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PERFORMANCE EVALUATION OF SOLAR GREENHOUSE DRYER FOR DRYING HERBALS

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ABSTRACT
A solar greenhouse dryer is specially designed for drying herbals. The designed system is efficient because, the energy is trapped in greenhouse system thus maintains high temperature and leads to drying of herbals in an efficient and quickly manner. The theoretical calculations of greenhouse solar dryer is calculated by using various parameters such as solar intensity, mass flow rate, slope angle of the dryer for two different areas (CASE-I 2m² and CASE-II 0.5m²) of greenhouse dryer. And suggested the experimental setup to be fabricated for CASE-II and conducted the performance test for measuring the moisture removal time, temperature variations, heat gain and effectiveness. To improve the life time of herbals storage without changing its aroma, colour, volatile content, etc by using solar greenhouse dryer.

INTRODUCTION
Drying is one of the most efficient methods used to preserve food products for longer periods. A solar dryer is an enclosed unit, to keep the food safe from damage, birds, insects, and unexpected rainfall. The food is dried using solar thermal energy in a cleaner and healthier way.Solar energy has been used for the preservation of agricultural produce since generations all over the world. Recent research on drying reveals the shortcoming of the open sun drying. In order to minimize the shortcoming of the open sun drying, various drying techniques are proposed.

A greenhouse solar dryer consists of a green house as a collector linked to a wooden stack chamber. The dryer has trays stacked inside a wooden shed. Trays are fixed in the wooden chamber to spread banana. The fan and plastic film together forms an efficient solar collector system, which can increase the air temperature inside the green house by about 20°C. Heated air inside the green house passes through the trays stacked in the wooden chamber. In order to obtain a regular air flow through the trays, a fan is placed on the rear side of the stack chamber. Heated air inside the green house passes through the trays stacked in the wooden chamber.

THEORETICAL MODEL
DETERMINATION OF DRYING RATE
The moisture removal rate is calculated by given as

$$MR = \frac{m_i - m_f}{t_d} \qquad \text{(kg/s)}$$

where,
m_i Mass of sample before drying, kg
m_f Mass of sample after drying, kg
t_d The drying duration time, s

MOISTURE REMOVAL RATE
The moisture loss is given by

$$MR = \frac{m_i - m_f}{m_f} \qquad (\%)$$

where,

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m_i Mass of sample before drying, kg
m_f Mass of sample after drying, kg

FLUID FLOW CHARACTERISTICS

Reynolds Number

Reynolds number is defined as the ratio of inertia force and viscous force.

$$Re = \frac{\rho V D_h}{\mu}$$

where,

$\dot{m}$ Mass flow rate of air, kg/s
μ Absolute viscosity of air, Ns/m²
ρ Density of the air, kg/m³
v Velocity of air, m/s
A_c Cross sectional area of the dryer, m²
D_h Hydraulic diameter, m

$$D_h = \frac{4(W \times H_a)}{2(W + H_a)} \quad \text{(m)}$$

where,
H_a Average height of the dryer, m
W Width of the dryer, m

Nusselt Number

Nusselt number is defined as the ratio of convective heat transfer to heat transfer by conduction in the fluid and involve the heat transfer co-efficient (h) and thermal conductivity.

$$Nu = 0.0.158 \times Re^{0.8}$$

HEAT TRANSFER CO-EFFICIENTS

Radiation Heat Transfer Coefficient between the Cover to Sky ($h_{r,c-s}$)

$$h_{r,c-s} = \varepsilon_c \sigma (T_c^2 + T_s^2)(T_c + T_s)$$

where,
σ Stefan – boltzman constant, Wm²K⁴
ε_c Emisivity of the cover
T_c Cover temperature, K
T_s Sky temperature, K

Radiation Heat Transfer Coefficient between the Product to Cover ($h_{r,p-c}$)

$$h_{r,p-c} = \varepsilon_p \sigma (T_p^2 + T_c^2)(T_p + T_c)$$

where,
ε_p Emisivity of the product
T_p Product temperature, K

Convective Heat Transfer Coefficient (h_c)

$$h_c = \left(\frac{Nu \times k_a}{D_h} \right)$$

where,
Nu Nusselt number
k_a Thermal conductivity of air, W/mK

Convective Heat Transfer Coefficient between Cover to Ambient (h_w)

$$h_w = 5.7 + 3.8 V_w \quad \text{(W/m}^2\text{K)}$$

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OVERALL HEAT LOSS CO-EFFICIENT FROM THE COVER (U_c)

$$U_c = \frac{k_c}{\delta_c} \qquad (W/m^2K)$$

where,

k_c Thermal conductivity of the cover, W/mK
δ_c Cover thickness, m

EXPERIMENTAL SETUP

The Figure 1 shows the experimental set up of the solar green house dryer. It consists of steel structural frame with one wooden tray and entire setup would be covered with green house sheet. It is use for solar radiation trapped in inside dryer (1m x 0.5m x 0.75m – Length x Width x Height).

Figure 1 Solar Greenhouse Dryer

DRYING PRODUCTS

The Table 1 shows the botanical and tamil name of the herbals (drying products).

Botanical name	Tamil name
Jesticia adhatoda	Adhatoda
Solanum trilobatum	Thuthuvalai
Phylanodiflora	Podudhalai
Alstrnia scholaris	Paalamaram

Table 1 Herbals Name

The Table 2 shows the tamil name, uses, photos of the selected herbals (drying products).

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S.No	Tamil name	Uses	Photos
1	Adhatoda	Cough, cold, Bp, TB, fever, asthma	
2	Thuthuvalai	Cold, cough, fever	
3	Podudhalai	Ulcers, pustules, anti-dandruff medicine	
4	Paalamaram	Nausea and vomiting, dry mouth, muscle twitch	

Table 2 Herbals Details

RESULTS AND DISCUSSION

The comparison of theoretical and experimental results are shown in Table 3. The important parameters are compared and tabulated below. The heat gain from experimental value (182.68W) is greater than theoretical value (153.14 W). Because the performance test is conducted on summer season (April, May). This month is peak for solar radiation.

S.NO	PARAMETER	THEORITICAL RESULT	EXPERIMENTAL RESULT
1	Reynolds number	671.7	7388.75
2	Nusselt number	2.89	19.66
3	Radiative heat transfer co efficient (C-S)	0.025	0.053
4	Radiative heat transfer co efficient (P-C)	0.016	0.018
5	Convective heat transfer co efficient	0.142	0.97
6	Heat gain	153.14	182.68

Table 3 Comparison of Theoretical and Experimental Values

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The drying measurements like date, weight of drying product before drying, weight of drying product after drying, starting time, ending time are tabulated. And also the drying rate and moisture removal rate are calculated and tabulated. The values are shown in Table 4.

S.NO	NAME	DATE	WT.B.D	ST	WT.A.D	CT	DR	MRR
			g	hrs	g	hrs	g/hr	%
1	aadadhoda	15.04	222	10	128	16	15.67	42.34
2	aadadhoda	16.04	284	10	136	16	24.67	52.11
3	aadadhoda	17.04	305	10	117	16	31.33	61.64
4	paalamaram	20.04	125	10	42	16	13.83	66.40
5	paalamaram	21.04	150	10	64	16	14.33	57.33
6	paalamaram	22.04	142	10	45	16	16.17	68.31
7	poduthalai	23.04	285	10	163	17	17.43	42.81
8	poduthalai	25.04	296	10	146	17	21.43	50.68
9	poduthalai	26.04	324	10	174	17	21.43	46.30
10	thuthuvalai	27.04	394	9	145	16	35.57	63.20
11	thuthuvalai	28.04	350	9	137	16	30.43	60.86
12	thuthuvalai	29.04	367	9	155	16	30.29	57.77

Table 4 Drying rate and Moisture removal rate for various products and various dates

The variation of DR, MRR with respect to change of days for Aadadhoda is shown in Figure 2

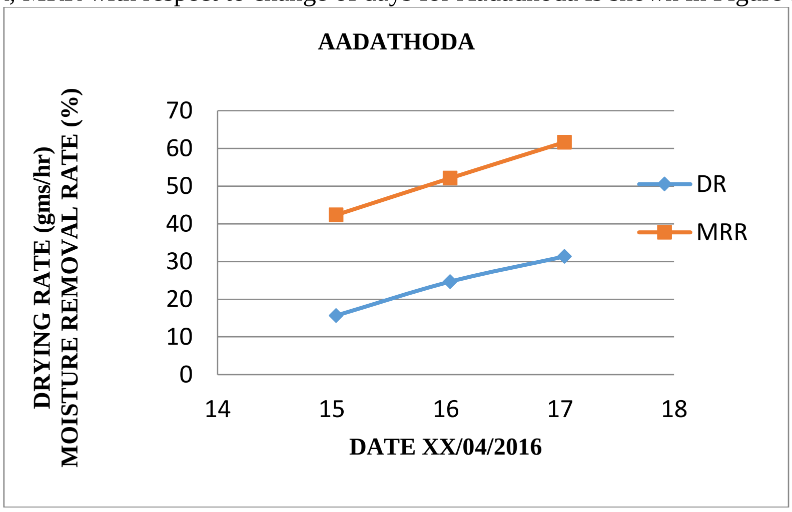

Figure 2. Change DR,MRR with respect to Date for Aadadhoda

The variation of DR, MRR with respect to change of days for Paalamaram is shown in Figure 3

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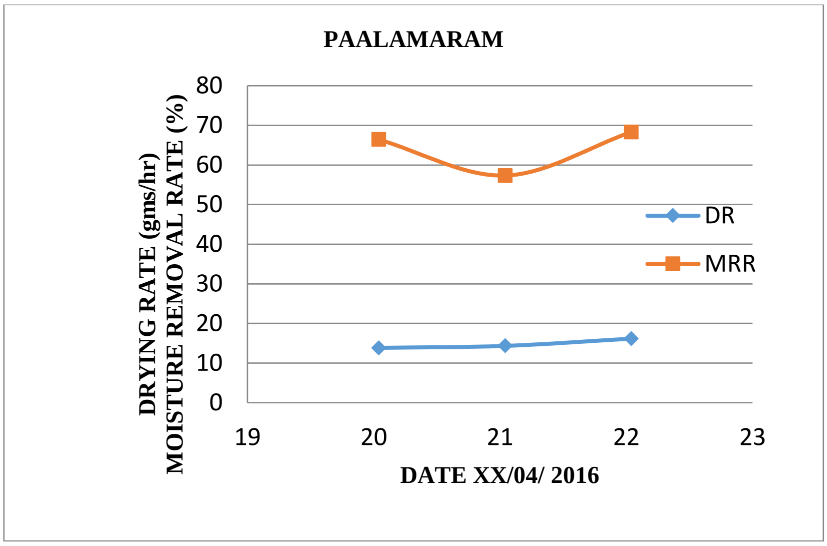

Figure 3. Change DR,MRR with respect to Date for Paalamaram

The variation of DR, MRR with respect to change of days for Poduthalai is shown in Figure 4

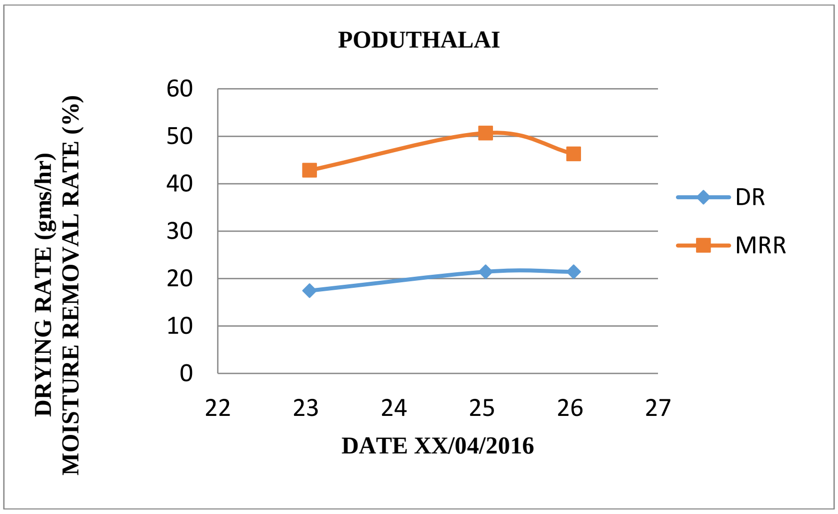

Figure 4. Change DR,MRR with respect to Date for Poduthalai

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The variation of DR, MRR with respect to change of days for Thuthuvalai is shown in Figure 5

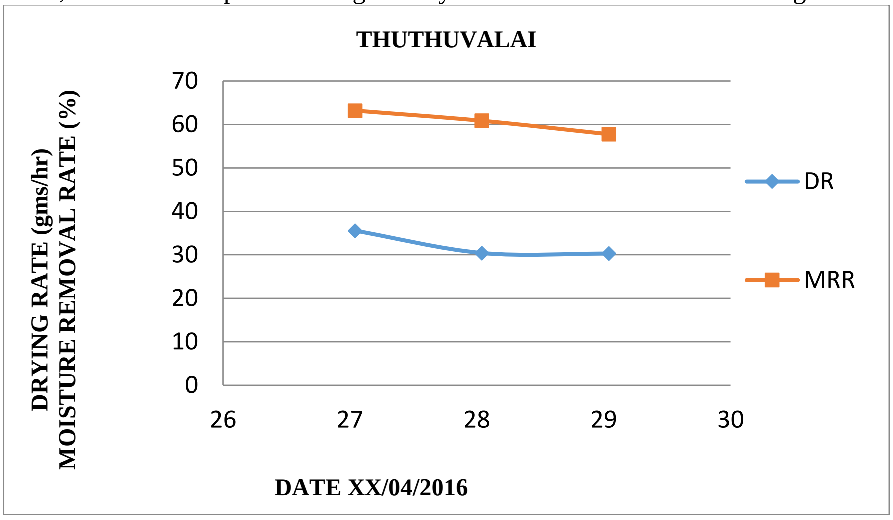

Figure 5. Change DR,MRR with respect to Date for thuthuvalai

The variation of Atmospheric temperature with respect to change of time for different days are shown in Figure 6

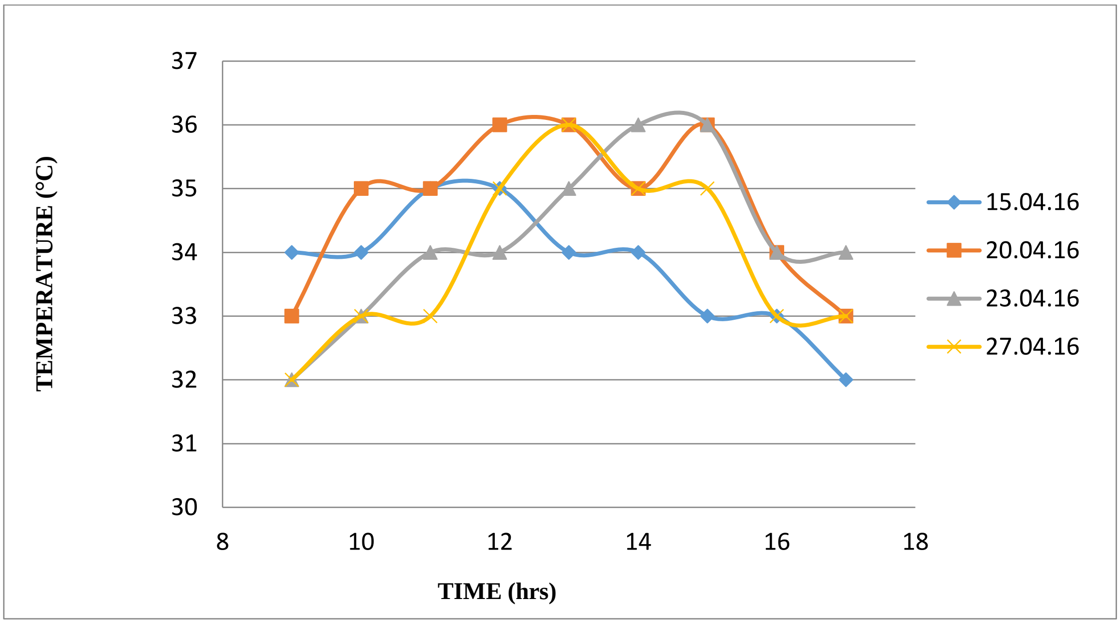

Figure 6 Atmospheric Temperature with respect to Time

CONCLUSIONS

Based on the theoretical and experimental work following conclusion were arrived,

- The heat gain of the green house solar dryer was achieved 437.57W and 153.14W for Case-I and Case-II respectively.
- Two sizes of design each having size of Case-I & Case-II (2m² & 0.05m²). The maximum efficient heat gain of dryer obtained from the Case-II.
- The herbals drying rate are achieved from this setup 23.89 g/hr for aadadhoda, 14.78 g/hr for paalamaram, 20.01 g/hr for poduthalai, 32.10 g/hr for thuthuvalai.
- The herbals moisture removal rates are arrived from this setup 52.03% for aadathoda, 64.01% for paalamaram, 46.60% for poduthalai, 60.61 for thuthuvalai.

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- This above drying rate and moisture removal rate values are greater than open and shadow drying. This is one of the most suitable drying method for drying herbals.

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